

Booster Wide Aperture D-Magnets for PIP-I+ and PIP-II

Functional Requirements Specification

March 14, 2019

Document number: Beams-doc-7088-V1

Document Approval

Signatures Required	Date Approved
Originator: Chandrashekhara M Bhat, Project Manager	
Approver: Cheng- Yang Tan, Department Head and Project Director	
Approver: Mary Convery, AIP Program Coordinator	
Approver: Lia Merminga, PIP-II Project Director	
Approver: Michael Lindgren, Accelerator Division Head	

Revision History

Revision	Date of Release	Description of Change
A		Initial release

Table of Contents

- 1. Purpose 4
- 2. Scope 4
- 3. Acronyms 4
- 4. Reference 4
- 5. Key Assumptions 5
- 6. Functional Requirements 5
- 7. Safety Requirements 5

1. Purpose

This FRS documents functional requirements for three wide aperture D-magnets at 8 GeV extraction. This upgrade is to reduce losses at extraction. Since PIP-I+ is an essential transition piece to PIP-II, the problems identified and mitigated in PIP-I+ will be applicable to the success of PIP-II.

2. Scope

This FRS addresses the functional requirements of

- i. Wide aperture D-magnets at 8 GeV extraction that includes design, fabrication, assembling on a test bench, testing, field quality measurements as required for beam physics modeling.
- ii. Refurbish the girder for installation of the two D-magnets, installation of the magnets in the Booster ring that includes design, modifications to fixtures for power supplies keeping the Booster lattice unchanged. Commissioning of the magnet assembly with proton beam.
- iii. These magnets should operate at 15 Hz during PIP-I+ era and at 20 Hz during PIP-II era.

3. Acronyms

FESHM	Fermilab ES&H Manual
FRCM	Fermilab Radiological Control Manual
FRS	Functional Requirements Specification
PIP	Proton Improvement Plan
PIP-I+	Proton Improvement Plan I+ AIP
PIP-II	Proton Improvement Plan -II
2SC	Two Stage Collimator
CHG0	Charge zero detector
DCCT	Direct current Transformer
SCD	System Configuration Document
HLRF	High Level RF
LLRF	Low Level RF
HEP	High Energy Physics
ppp	protons per pulse
TC	Teamcenter
WBS	Work Breakdown Structure

4. Reference

#	Reference	Document #
1	PIP Design Handbook	Beams-docs-4053 (2012)

2	Fermilab Engineering Manual	NA
3	Fermilab Environmental Safety and Health Manual	NA
4	Fermilab Radiological Control Manual	https://eshq.fnal.gov/manuals/frcm/
5		

5. Key Assumptions

Conventional utilities (painting, lighting, fire protection, sump/drainage, impediments) cable trays and work on penetrations will be outside the scope of this FRS and completed prior to wide aperture D-magnet installations. But, the FTE and M&S cost related to refurbishing the existing magnet grider at extraction location is part of this WBS. Any M&S cost related to acquire new computers/computer software for magnet design are outside the scope of this FRS.

6. Functional Requirements

- i. Inject $5.2E12$ protons per Booster cycle from the current 400 MeV LINAC by multi-turn injection and extract $4.93E12$ ppp from the Booster at 8GeV at 15Hz with longitudinal emittance of 0.1 eVs and normalized transverse emittance of 16π -mm-mrad at the completion of PIP-I+.
- ii. Currently, $\sim 4.3E12$ ppp is extracted at 15Hz from the Booster. The average radiation level in the Booster beam extraction region MPO2 is about 600 mR@1ft which comes from scraping of the beam particles in tail region of the beam's transverse distribution as it traverses through the D-magnets. This will go up by $\sim 16\%$ for PIP-I+ intensity and another 33% by increasing the repetition rate from 15 Hz to 20 Hz for PIP-II. By increasing the D-magnet aperture from 2.25in to 3in the beam loss due to beam scraping can be reduced by about 33%. Widening the aperture will benefit PIP-I+ as well as the PIP-II.
- iii. These magnets should be tested and capable of operating at 15 Hz as well as 20 Hz with necessary magnetic field quality as needed by PIP-I+ and PIP-II operation, respectively.

7. Safety Requirements

Engineering, design, fabrication, assembly and tests of the given system shall abide by Fermilab ES&H (FESHM) and all Fermilab Radiological Control Manual (FRCM) requirements.

Any changes in the applicability or adherence to these standards and requirements require the approval and authorization of appropriate authority.

In addition, the following codes and standards in their latest edition shall be applied to the engineering, design, fabrication, assembly and tests of the given system.